

6.4 Technical Review

April 7- 10, 2015

Project: Modeling Sensing and Forecasting Ocean Optical Products for Navy Systems: Tactical Ocean Data System (TODS)

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P. Lyon – NAVO



Modeling, Sensing and Forecasting Ocean Optical Products for Navy Systems- TODS

Summary of Capabilities, Accomplishments and Plans



Summarize FY14-15 Delivered Capability

- Provides naval operations with a 2D/3D real time and forecast optical characterization capability of the battlespace by fusing gliders, satellites and ocean models
- Warfighter nowcast/forecast performance surfaces to support laser and camera imaging systems (AN/AQS, bathy lidar, AMNS, ALMDS), passive EO sensors, EO bathy systems, and diver operations (visibility/vulnerability)
- Products currently target fleet MIW (HM-14, HM-15) Reach Back Cells for mission planning and operations.

FY14-15

Accomplishments/Challenges/Issues

- BioCast enhancements/upgrades (coastal numerical stability, bathy anomalies, land/water boundary issues, additional evaluation).
- Bathygen software upgrade (subsampling of GEBCO database for memory reduction < 2GB for NAVO virtual system requirement)
- 3DOG upgrades for full end-to-end automation and efficiency
- BioCast v1.0 additional validation during TW2013
- BioCast v1.0 Delivered w/ VTR Q2FY14
- BioCast v1.0 software and Bathygen upgrades and VTR approval Q4FY14
- BioCast v1.0 OPTTEST started Q1FY15 and is ongoing.

Challenges/Delays due to: 1) required software enhancements and improved automation for operational efficiency, 2) additional validation requirements/exercises, 3) delay in BioCast v1.0 VTR acceptance, 4) new NAVO laser performance model (3DOG), and

Summarize FY15 Plans

- Complete BioCast v1.0 OPTTEST at NAVO including validation of forecast outputs for 2 areas over 3 month period (complete with report by Q3FY15 for final acceptance).
- Continue evaluation of 3D Optical Volume Generator (3DOG) v1.0 during additional exercises (NAVO NP331 Request) and finalize VTR and user's manual if funding permits. (Planned transition of 3DOG v1.0 Q2FY16)
- No additional transitions expected in FY15 due to funding cut (<20% FTE) and loss of recently trained personnel familiar with project/software to other projects/support.

Funding

(\$K)	FY13	FY14	FY15	FY16
TODS	235	215	48	330
Total	235	215	48	330

FY16 1498 submitted to TOC-USW



Modeling, Sensing and Forecasting Ocean Optical Products for Navy Systems- TODS

FY14-15 Major Objectives & Milestones



MS Event/Action/Improvement Objective	Completion and/or Delivery Quarter/FY	Description of Capability Completed and/or Delivered
Optical Forecast (BioCast v1.0)	Delivered with software and VTR updates 4QFY14, OPTEST started Q1FY15 (ongoing)	Provides 3D forecasts using homogeneous volume (satellite surface optics extended vertically) w/ output 2D surface coastal optical properties for water clarity, diver visibility/vulnerability and lidar penetration depth
Bathymen v1.0	Upgrade delivered in Q4FY14 - memory issues fixed reading in GEBCO database	Software developed to consistently generate bathymetry from supplied DBDB2 and GEBCO databases to match satellite grid from AOPS for BioCast and 3DOG.
3D Optical Volume Generator v1.0 (3DOG)	Delivery w/VTR Q2FY16 OPTEST to follow	Provides nowcast/forecasts of the 3D optical environment by fusing gliders, satellites and ocean models in support MIW diver and laser imaging operations.
Laser Performance Surfaces	Delivery in 2QFY16 - integrated into 3DOG software to enhance operational timeliness	Provides performance surfaces to support laser and camera imaging systems (AN/AQS, bathy lidar, AMNS, ALMDS), passive EO sensors, EO bathy systems, and diver operations (visibility/vulnerability)



Modeling, Sensing and Forecasting Ocean Optical Products for Navy Systems- TODS

Milestone Chart



Tactical Ocean Display System (TODS)

	FY13				FY14				FY15				FY16			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
(1) Forecast Optical Properties (3D Biocast v1.0)	S		S	C	V	O		C	V	O						
(2) 3D Optical Generator (3DOG) w/ AQS-24 System Performance (EODESv1.0)						S	C	V	O			S	C	V	O	
(3) BioCast v2.0 Complete 3D Forecasts										S				S		
(4) Planned Exercises / Demonstrations			D _{TW}				D				D _e	D _{miw?}				

- BioCast v1.0:** 100% complete, Software Upgrade / Bathygen Upgrade / updated VTR delivered 4QFY14
2D Only *Delays due to needed operational software enhancements and improved automation, numerical stability in coastal regions, additional evaluation and validation during Trident Warrior Q32013, TP acceptance delays, AOPS Transition, NAVO IT issues with transfer of satellite properties from low to high side (HSG), and Bathygen upgrade to subsection bathy databases for memory compliance (<2G).*
- 3DOG v1.0:** 80% complete , Planned Transition w/ VTR Q2FY16.



Modeling, Sensing and Forecasting Ocean Optical Products for Navy Systems- TODS

FY14-15 Transition Plan Summary



- **TRANSITION APPROVAL STATUS:**

1. FY14 TP approved, FY15 Addendum approved by NAVO, PMW120, CNMOC and OPNAV.

- **INPUTS**

1. AOPS derived satellite ocean color imagery (MODIS-Aqua, SNPP VIIRS, GOCI and future Sentinel 3A, GOCI2, SGLI, JPSS1 VIIRS)
2. Insitu physical and optical data (quality controlled) from gliders and BSP/AEP
3. Bathymetry grid that matches Satellite grid (Bathygen)
4. Regional Numerical models (RELO-NCOM, HYCOM)

- **OUTPUTS / PRODUCTS:** Outputs from these transitions will advance and deliver near real time high resolution fused and integrated optical oceanographic products which can be used to support a variety of Navy missions, especially MIW:

1. A 2D/3D forecast of coastal ocean optical properties for the performance surfaces to support camera and laser imaging systems (AN/AQS 20/24, AMNS, ALMDS),
2. Swimmer/target performance surfaces (visibility and vulnerability, and
3. A performance surface for deployment of active and passive EO bathymetry systems (e.g. CHARTS)

- **ACCEPTANCE CRITERIA:**

1. Evaluation at NRL with resulting VTR acceptance at NAVO and pass NAVO OPTTEST with NRL validation and evaluation preferably during fleet exercises. If fleet exercise not available, then data from coastal Navy science exercises will be substituted.
2. VTR will include validation using glider data with TOD's outputs and Navy fleet system outputs (ex. AQS snippets) when available.
3. Successful OPEVAL at NAVO that will involve installation and testing the transitioned software on NAVO systems for a 2 month period.

- **OPERATIONS AND MAINTENANCE REQUIREMENTS**

1. 2 months for OPEVAL and training will be required.
2. 1 FTE will be required to run operationally after transition.



Modeling, Sensing and Forecasting Ocean Optical Products for Navy Systems- TODS

IMPACT of Possible FY16 Funding Termination



- The full capability of the TODS' system to provide real-time/forecast 3D optical products (with subsurface optical layer information) and diver and laser system performance to MIW operations and mission planning cannot be completed by the end of FY15.
- Only the surface optical forecasting capability can be completed.
- Impacts of FY16 funding cut:
 - No real-time (3DOG) and forecast 3D (BioCast v2.0) optical capability (water clarity, diver and SDV visibility /vulnerability and laser system performance) to support MIW mission planning and operations (detection, identification and clearing).
 - MIW Fleet operational impacts: loss in needed mission planning affecting time to complete clearing, a decrease in identification efficiency and an increase in asset and personnel risk.
 - Loss of talented NRL/contractor personnel familiar with the TODS system and software to other projects or new jobs and not available in FY16/17, loss of continuity on project requiring training of new personnel which would increase timelines and total cost to complete transition of TODS 3D optical forecasting capability.



Modeling, Sensing and Forecasting Ocean Optical Products for Navy Systems- TODS

Discussion Outline



- **TODS' Component Overview**
 - **BioCast, 3D Optical Volume, AN/AQS System Performance, Diver Visibility/Ops**
- **BioCast v1.0 Transition Status**
- **FY14/15 Software Updates**
 - **Bathygen**
 - **Optical Forecast - BioCast v1.0**
 - **3D Optical Generator v1.0**
- **3DOG v1.0 Validation**
 - **Trident Warrior 2013**
- **Exercise Plans**
- **Summary**
- ***Future Plans***



Modeling, Sensing and Forecasting Ocean Optical Products for Navy Systems- TODS

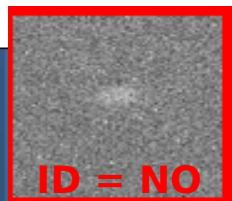
TODS Components Overview



- **LAGER** - Quality control of glider optical and physical properties
 - Deployment, Processing and data QC and analysis (**Transitioned**)
- **DISPLAY** - Real-time product display capability
 - Merging satellite and model products, insitu glider locations and forecast (BioCast) and 3D (3DOG) outputs (**Transitioned** / Required upgrade in FY16 see 1498 - Requested by Peter Flynn NP31)
- **BioCast v1** - 3D optical forecasting with surface 2D output (Homogeneous 3D Volume - Satellite Surface Value Extended Vertically)
 - Coupling Satellite optics and models (**Transitioned/ in OPTTEST**)
- **BioCast v2** - Complete 3D Optical Forecasting with 3D output (3D volume Input w/ subsurface layer info)
- **3DOG** - 3D Optical Volume Generator
 - Fusion of Gliders, Satellites and Models
- **MIW Performance Surfaces** (Laser Performance -> more efficient planning and reduced clearance time, Diver Visibility -> re-acquisition/id missions)
 - Linking the 3D optics with the AN/AQS 20/24 and Diver Operations

Capability to support the HM Squadron's AN/AQS 20/24 and Diver

ICM Operations using Gliders , Models and Remote Sensing



ID = NO

Towed
System

Clear Homogeneous



ID = YES

3D Optical
Environment

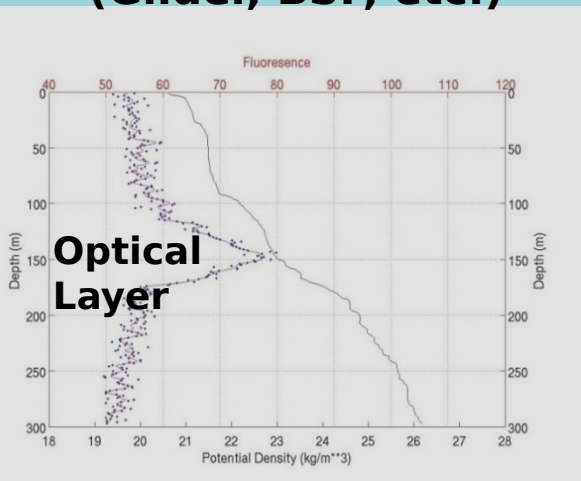
Turbid / Sediment Layers



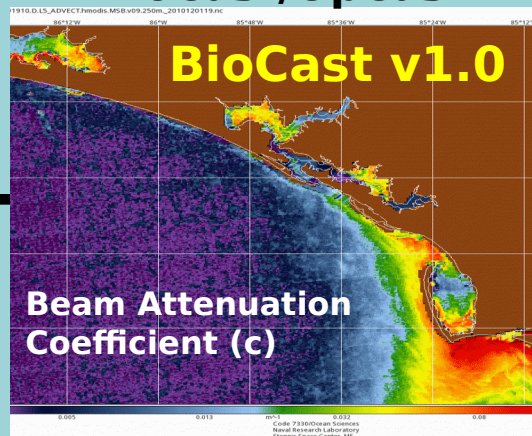
MODS Overview: Fusion of Glider Profiles, Satellite and Numerical Models to support AQS24 Operations

"Defining the optical environment for Navy Systems"

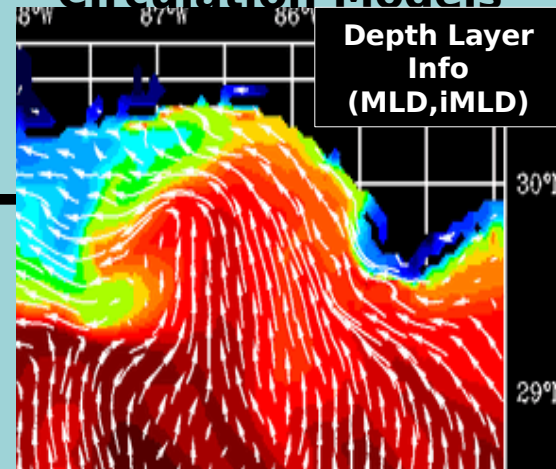
Vertical Optical Profiles (Glider, BSP, etc.)



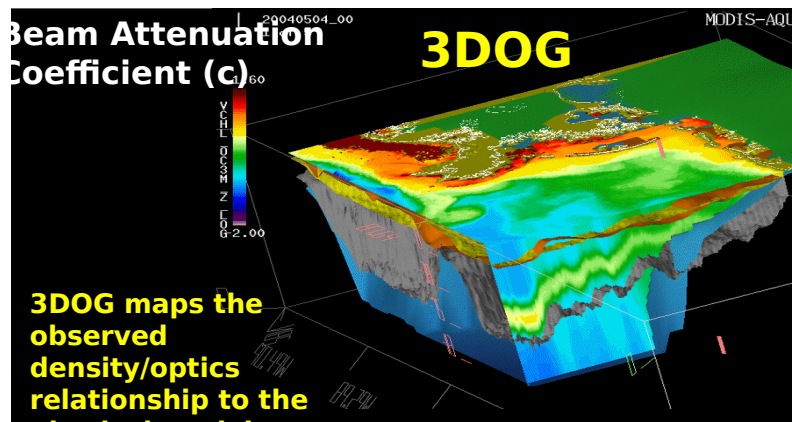
Nowcast / Forecast Satellite Optics BioCast/OpCast



Nowcast / Forecast Circulation Models



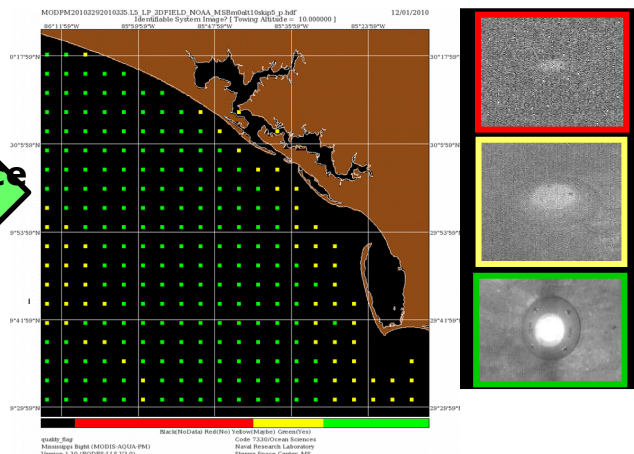
Optical Volume/Profiles & 3D Diver Visibility



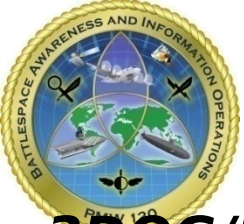
AN/AQS24 Performance Model

Beam Attenuation Coefficient (c) Profiles

Nowcast/Forecast Performance Surface Image Quality & Optimal System Towing Altitude

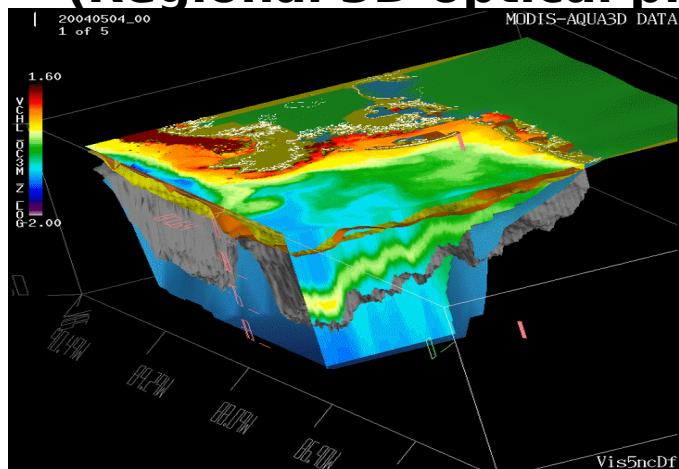


Insitu Physics/Optics Used to Tune Coeffs in 3DOG

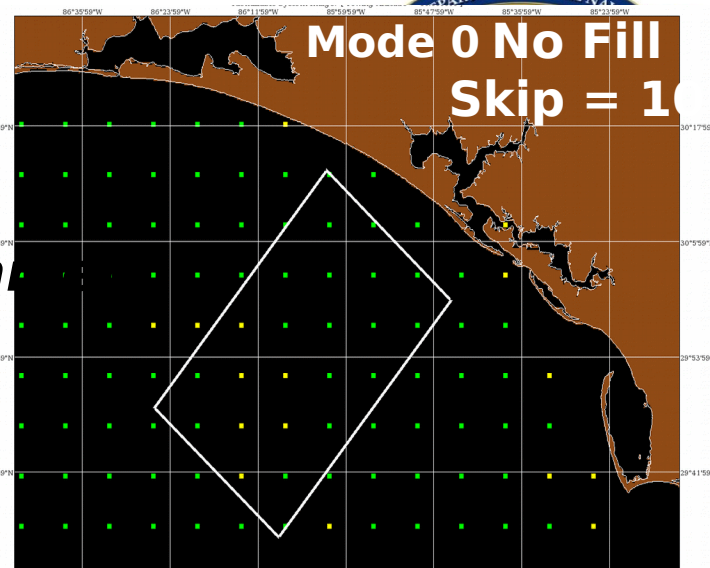


TODS MIW Laser Performance

3DOG/BioCast - Enhanced Regional Forecasting of the Operational Environment
(Regional 3D optical profile grid)

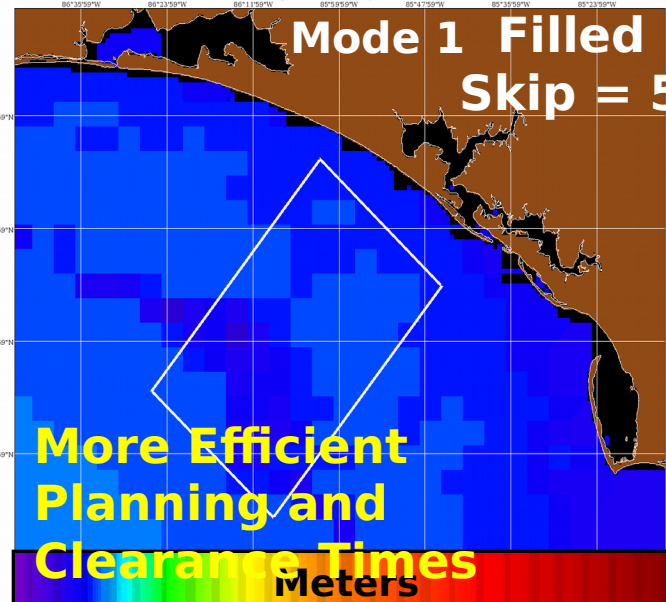


Regional Laser Imaging Performance Surfaces



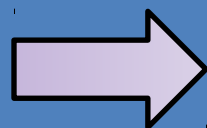
No Maybe Yes
Tow Altitude = 6m (Target ID?)

MODPM2103292010335.L5_LP_3DFIELD_NOAA_MS8m1akt0kap5.phd7 12/01/2010
Tow Depth: 6m Desired Probability = 10.000000



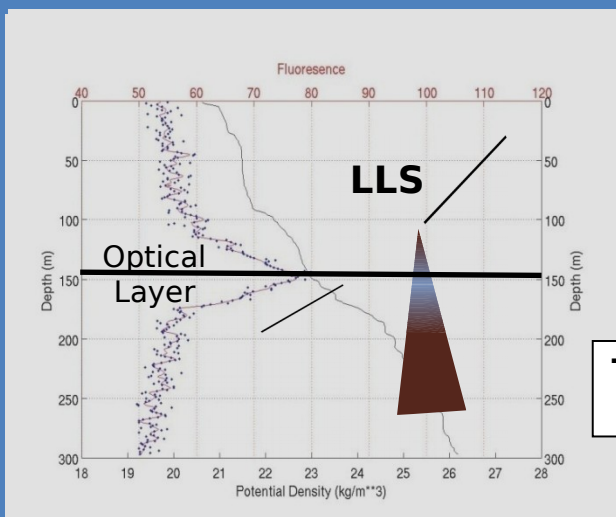
More Efficient Planning and Clearance Times
Meters
Sensor Optimal Tow Altitude

Point performance (BSP)



Tow Above/Below Optical Layer

Target ID?





Transition of BioCast for Optical Forecasting (Surface Only) - Version 1.0



BioCast VTR

- Capability to forecast surface bio-optical properties in support of shallow water Mine Warfare Operations (diver, laser imaging system performance – AN/AQS 20/24, lidar penetration depth and water clarity)
- Delivered Upgrade / User's Manual to NAVO (4QFY14)
- NAVO final VTR acceptance
- OPTEST started Q1FY15 and ongoing for 2 regions (Pohang Korea and Central Persian Gulf)
- Validation of OPTEST results completion by Q3FY15

VTR Highlights:

- 27 pages
- Test Case 1: Optical forecast validation in Miss Bight (Dec 2011- Oct 2012) with comparisons to OpCast v2.0 (2D advection)
- Results show BioCast had better error distributions
- Test Cast 2: Optical forecast (24 Hr) validation during Trident Warrior 2013.
- Results show forecast better than persistence.

Naval Research Laboratory

Stennis Space Center, MS 39529-5004



NRL/MR/7330-15-9525

Validation Test Report for the BioCast Optical Forecast Model Version 1.0

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NRL Memorandum Report - In Press

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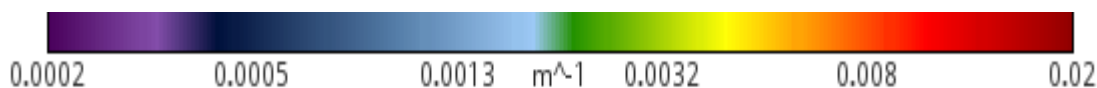
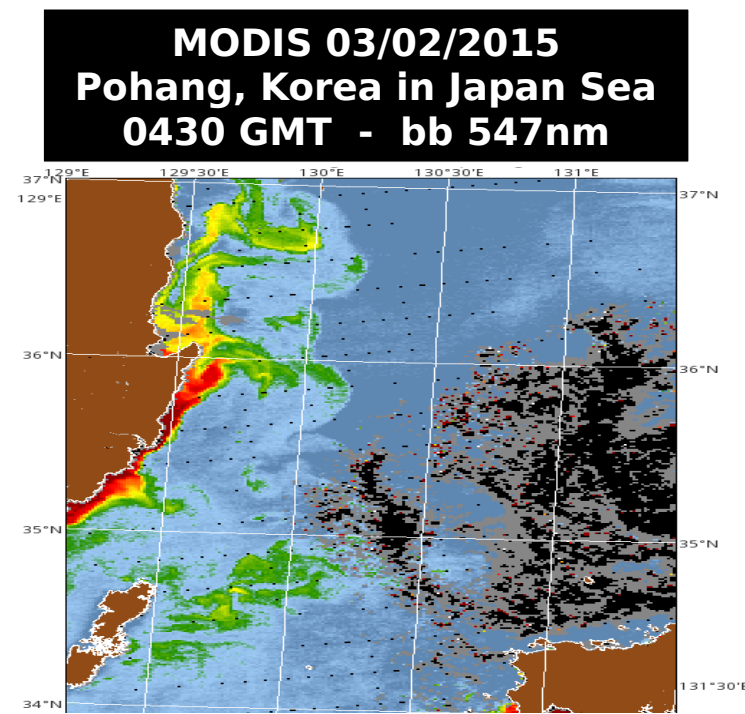
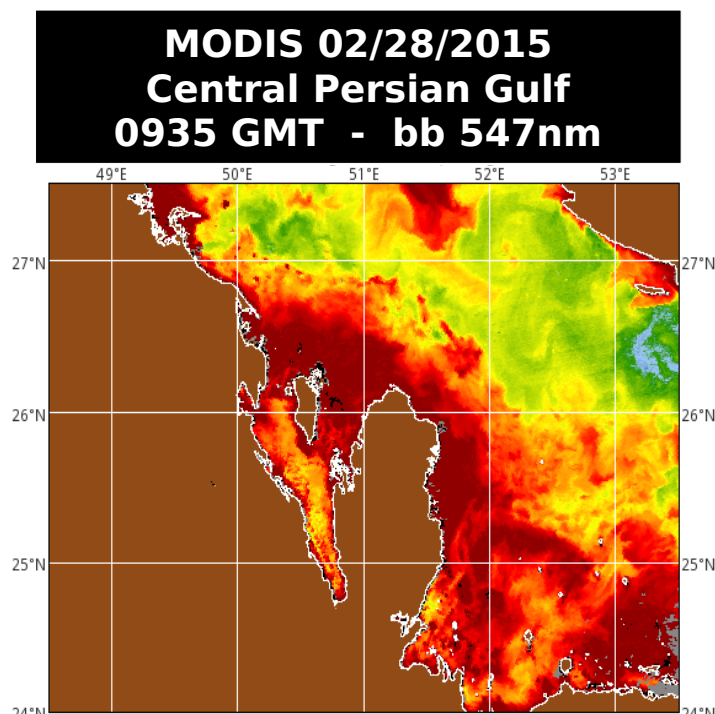


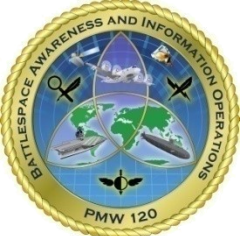
Modeling, Sensing and Forecasting Ocean Optical Products for Navy Systems- TODS

BioCast v1.0 OPTTEST (Ongoing)



- BioCast daily 24/48 hour forecast for 3 month period (ongoing)
- Evaluate 24/48 hour forecasts using next day's image for 3 consecutive clear days and compare to persistence
- Submit report to NAVO for review/acceptance





Modeling, Sensing and Forecasting Ocean Optical Products for Navy Systems- TODS

FY14/15 Software Updates



Bathygen

- Modified software to subsample GEBCO database for memory usage reduction < 2GB for NAVO system and increased speed by a factor of @20x

Optical Forecast - BioCast v1.0

- Improved coastal numerical stability
- Fixed issues due to handle anomalies in bathymetry database
- Fixed issues with land/water boundary
- Additional validation during Trident warrior (July 2013)
- Upgrade delivered and VTR approved Q4FY14; OPTTEST started Q1FY15 and is ongoing

3D Optical Generator v1.0

- Software modifications (scripting, Sed, Python and IDL) for end-to-end automated processing (glider file processing and QC, satellite pixel extractions, Gaussian model coefficient optimization, profile plots, 3D model run - 3D volume)
- Implemented methods to fully automate thinning of glider profiles during the optimization process using optimization statistics for optimal operational timeliness (visually hand-picking profiles is tedious, time consuming and not repeatable)
- Implemented and tested a capability to automatically exclude bad glider profiles during the satellite extraction process
- Implemented options to allow user to select predetermined coefficients and skip the glider optimization in cases where no glider assets are deployed or coefficients previously determined
- Implemented new evolutionary solver optimization toolkit - improved accuracy and speed
- Laser performance model integrated into 3DOG for faster production of laser performance surfaces
- Started documenting steps/processes from start to end (User's Manual) and VTR
- Continued testing and validation is ongoing and requires additional validation requested by

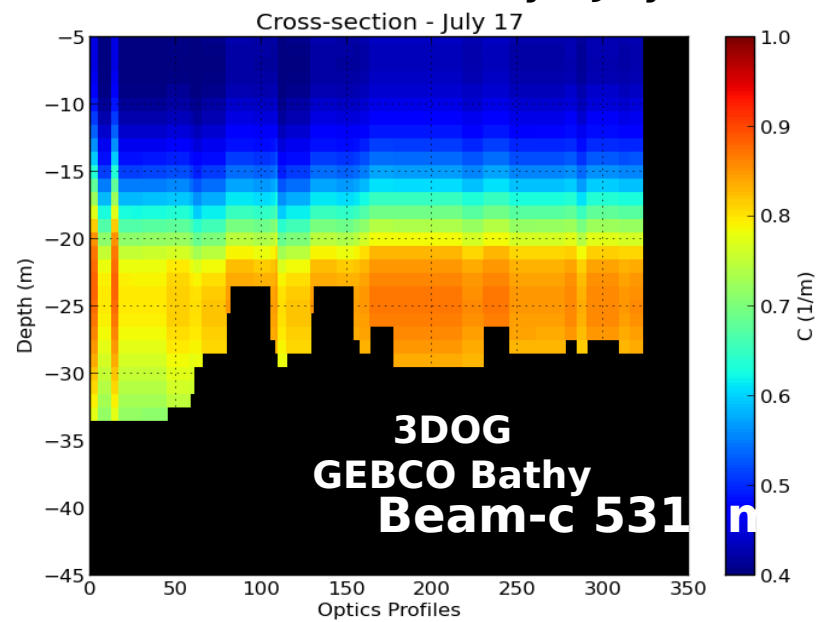
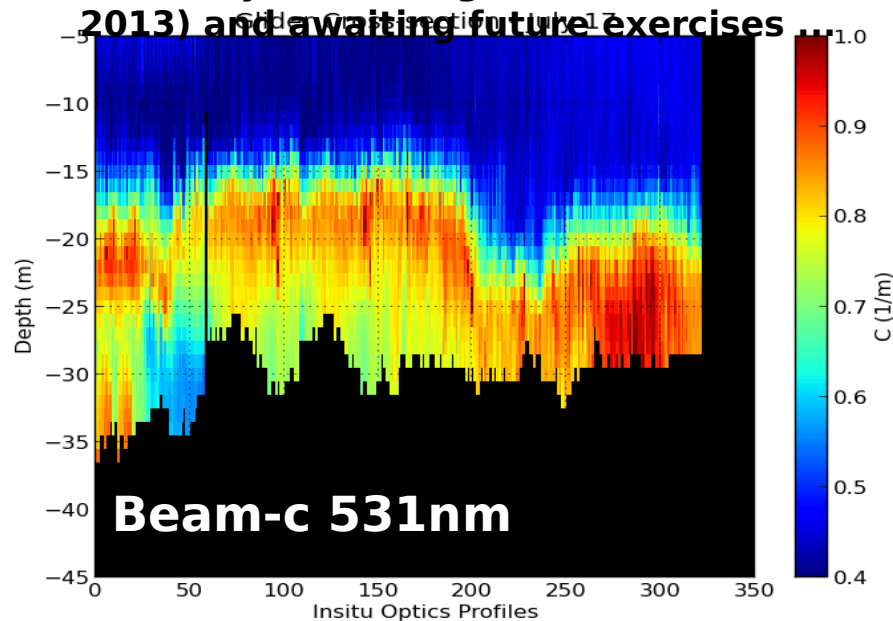


3DOG Validation - Trident Warrior 13 - July 17, 2013

Validation Results



- Numerous software improvements to operationalize code for enhanced automation and operational efficiency (auto glider QC, optimization, satellite extraction, 3D model)
- An optical (beam attenuation 531nm) layer is observed in glider and 3DOG profiles near bottom.
- The relationship between the observed and modeled optical fields is dependent on the fidelity of the physical model to the observations.
- Differences between observed and predicted possibly due to vertical resolution (5-10m bins > 10m) not capturing fine scale details in observations, MLD selection and bottom turbulence/sediment resuspension.
- Observations span 24 hours whereas satellite and model are coincident/static (time of satellite overpass) in 3DOG.
- Currently evaluating all Trident Warrior datasets for 3 clear satellite days (July 17-19, 2013) and awaiting future exercises





Modeling, Sensing and Forecasting Ocean Optical Products for Navy Systems- TODS

Exercise/Validation Plans - Northern Gulf of Mexico

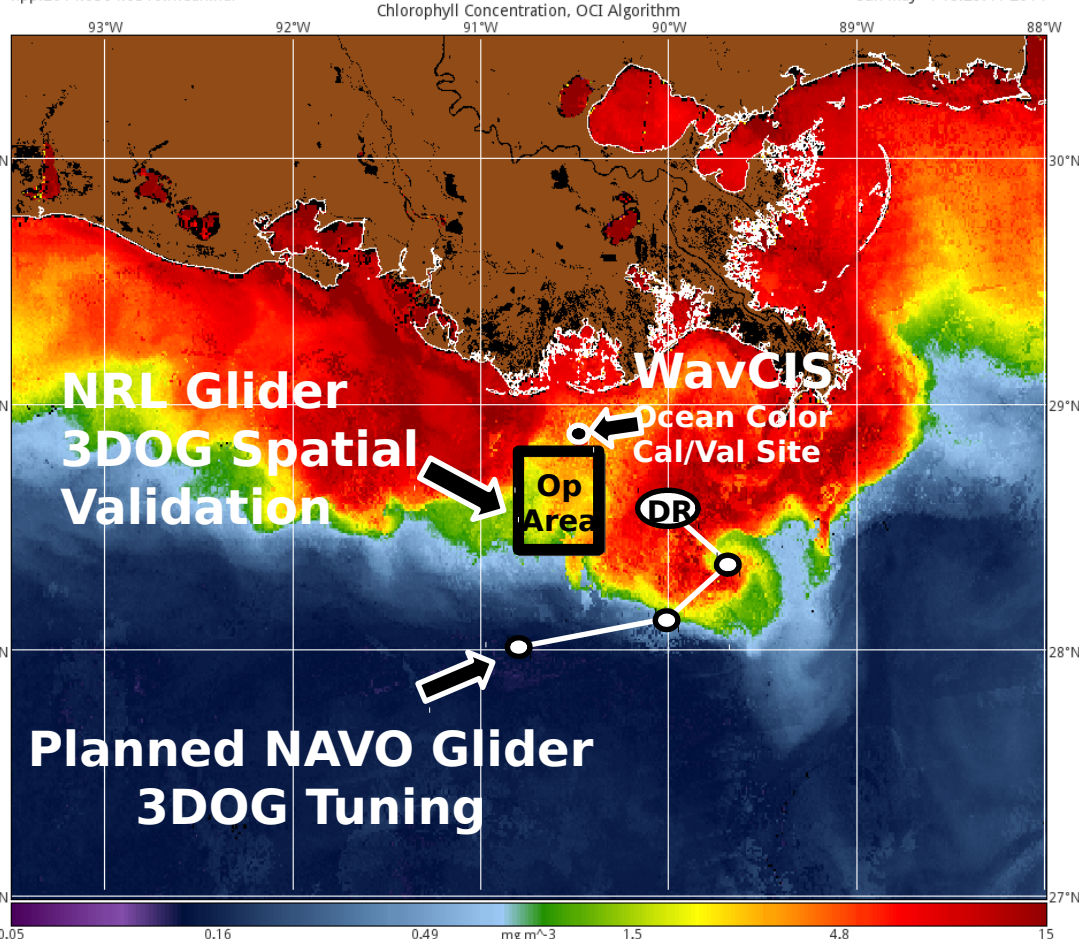


1 Plume-Case: Physical/Optical Consequences of River Plumes over the

npp.2014.0504.0510.mean.hdf

Chlorophyll Concentration, OCI Algorithm

Sun May 4 18:29:41 2014



6-21 June 2015: R/V Pelican

4 Mooring Sites

ADCP's

Wave/Tide

Optical Mooring / IOP's

High Resolution Temperature

DO (mini T/DO data-loggers)

Towed Platform

ScanFish: CTD, AC-9, BB3, FL

Gliders:

NRL Optics Glider - IOP's/CTD

Planned NAVO Optics Glider - IOP's

CTD

Glider w/ Microstructure Package

- CTD, Turb. Microstructure

Station Sampling:

HyperPro - AOP's, Irrad

Optics Package, IOP's

CTD, DO, FL

Fine-Scale Turbulence:

Wire Walker:

Turbulence Microstructure Profile

Turbulent Kinetic Energy Dissipation

+ Underway Measurements

+ METake from Ship, CSIOG

- Planning to participate in MIW exercise (none in last 3 years)
- Need to deploy multiple optics gliders for spatial



Modeling, Sensing and Forecasting Ocean Optical Products for Navy Systems- TODS

Summary



- BioCast v1.0 transition complete and currently going through OPTTEST at NAVO. Validation of 24hr forecast outputs for two regions once OPTTEST complete.
- Numerous software upgrades to improve BioCast v1.0, Bathymgen and 3DOG v1.0 operational efficiency with full automation optimization, satellite extraction, auto selection, thinning and QC of profiles for optimization.
- 3DOG validation ongoing (Northern GOMEX 6.1 buoyancy plume research and possible future Navy exercise)
- Need additional research leveraged and Navy exercises (NAVO request) for 3DOG validation/VTR: data collected by multiple gliders for spatial uncertainty. Will work closely with NAVO to find opportunities. In the past three years the opportunity to validate TODS' components in Navy exercises has been non-existent.
- No additional transitions expected in FY15 due to funding cut (<20% FTE) and loss of recently trained personnel familiar with project/software to other projects/support.
- This projects goal is to depict the real-time and predict the



Modeling, Sensing and Forecasting Ocean Optical Products for Navy Systems- TODS

Future Plans and Transitions

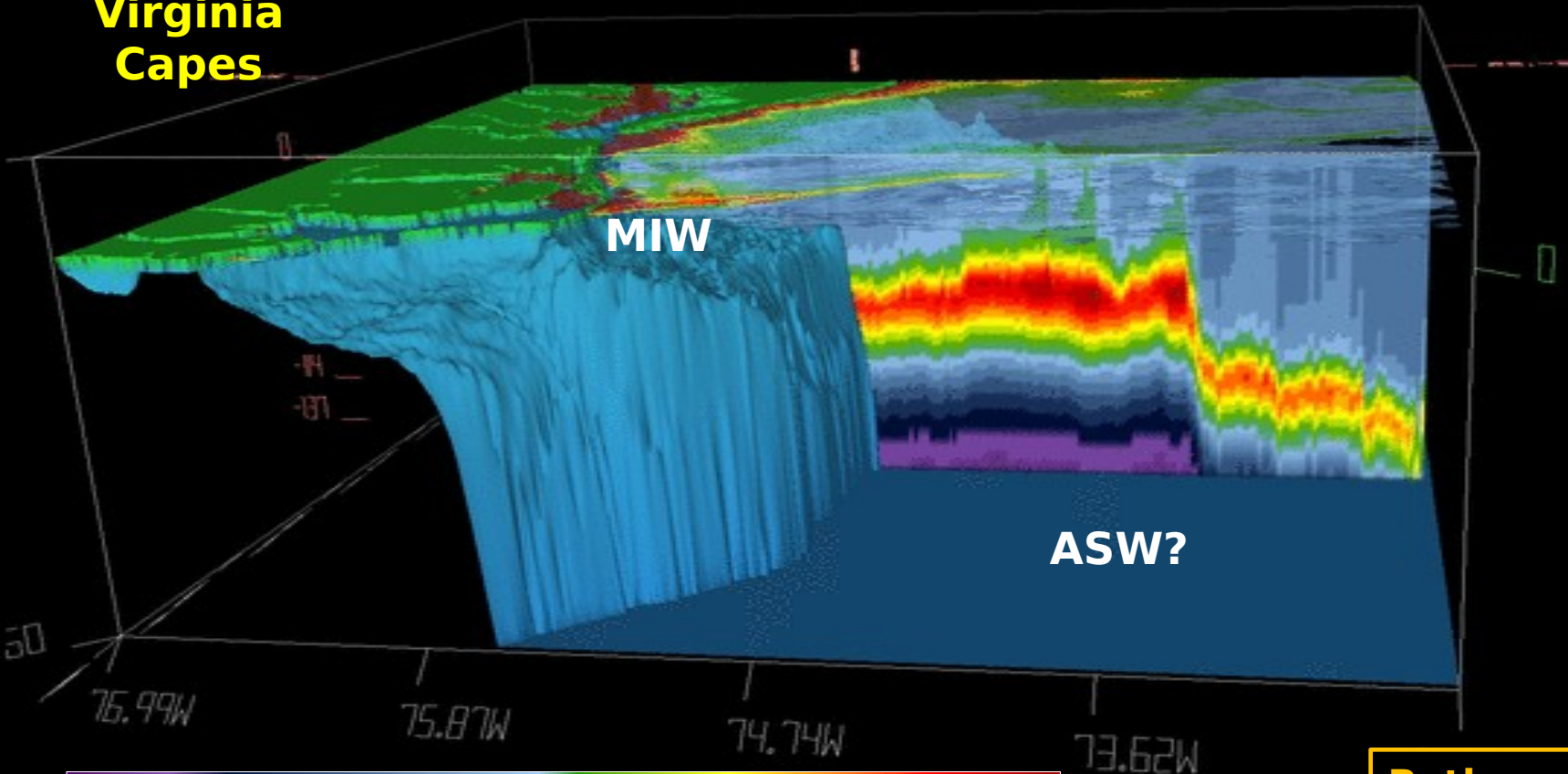


- Significant FY15 reductions (@78% from FY14) in TODS project and delays with FY14 transitions will push most development milestones and remaining transitions into FY16+ (See FY16 transition plan Addendum - Updated March 2015)
- 3D Optical Generator (3DOG) v1.0 with current planned delivery in Q2FY16 will provide nowcast 3D optical environment.
- BioCast v2.0 with current planned delivery in Q2FY17 will provide a full 3D optical forecasting capability using the nowcast 3D optical volumes from 3DOG v1.0 (containing modeled subsurface optical information including surface buoyancy, mid column (mixed layer) biology and nephloid sediment layers) as input including new enhanced 3D initialization volume upgrade.
- In FY17 we will evaluate the use of 3D optical nowcast and forecast for support of ASW vulnerability performance surfaces.
- BioCast v3.0 currently scheduled for transition in FY18 will include upgrades from NRL's Base 6.2 research project (PI: Jason Jolliff) starting Q1FY16: 1) Addition of new bottom layer optics / sedimentation and re-suspension processes model, 2) operational software enhancements

Trident Warrior 2013 July 17, 2013

3DOG Volume - Beam Attenuation 531nm

U.S. East Coast
Virginia
Capes



Beam-c (1/m) / Vertical Visibility (m)

0.34
14.1

0.47
10.2

0.64
7.5

0.88
5.4

1.2
3.8

Beam c
Vert Vis

Bathymetry
generated
using
Bathygen
GERCO



Transition of BioCast for Optical Forecasting (Surface Only) - Version 1.0



Naval Research Laboratory

Stennis Space Center, MS 39629-5004



NRL/MR/7330--15-9593

TODS BioCast User Manual
Forecasting 3D Satellite Derived Optical
Properties Using Eulerian Advection
Procedure
Version 1.0

Sean McCarthy
Jason Jolliff
Sherwin Ladner

Ocean Sciences Branch
Oceanography Division

NRL Memorandum
Report - In Press

Date Last Modified: 03/13/2015

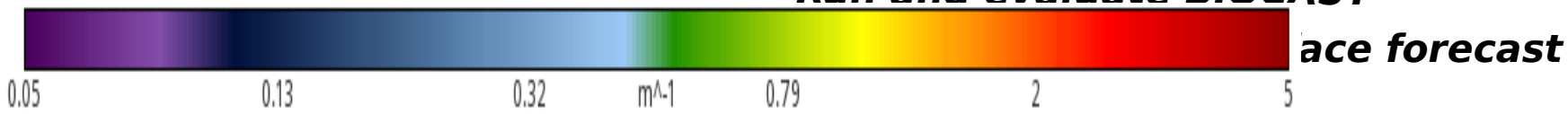
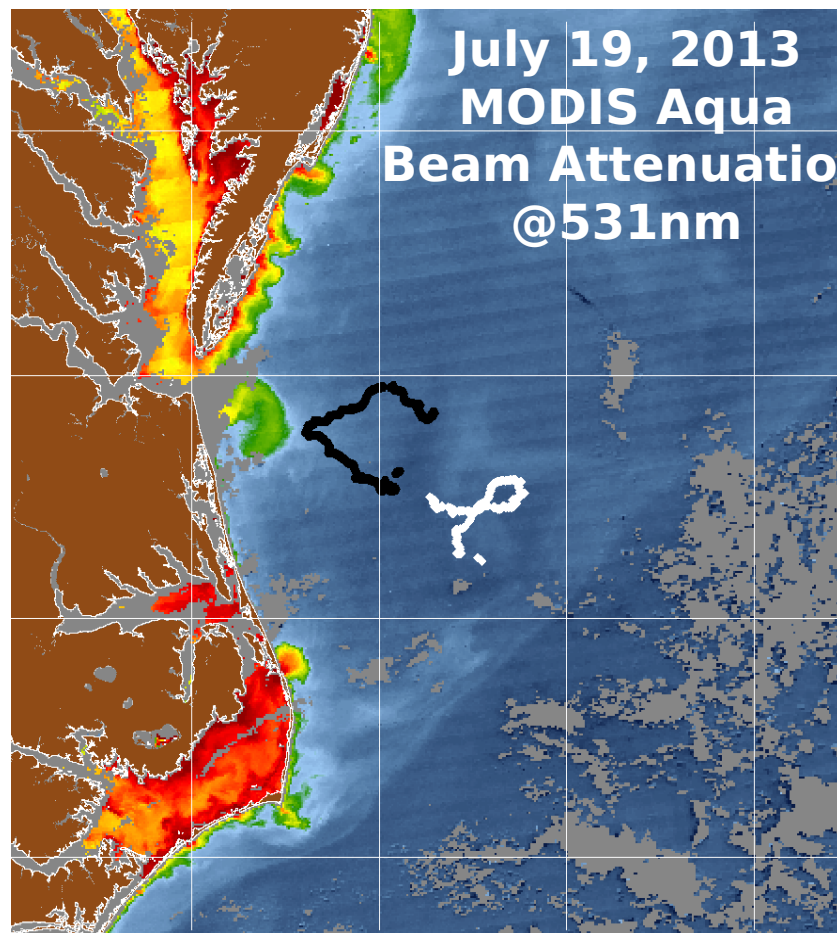


Trident Warrior July 2013

2D/3D Underwater Optics Forecast



U.S. East Coast Chesapeake Bay Virginia



OBJECTIVES:

1. ***Produce 3D optical distributions for the exercise area:***
 - ***Couple surface satellite ocean color imagery with glider data, model results (MLD depth, intensity) - 3D Optical Generator (3DOG).***
 - ***Deploy gliders to tune vertical coefficients in 3D optical model.***
 - ***Evaluate 3DOG software operationally.***
 - ***Validate 3DOG Optical Volumes (VTR).***
2. ***Forecast short-term surface optical distributions:***
 - ***Run and evaluate BIOCAST***



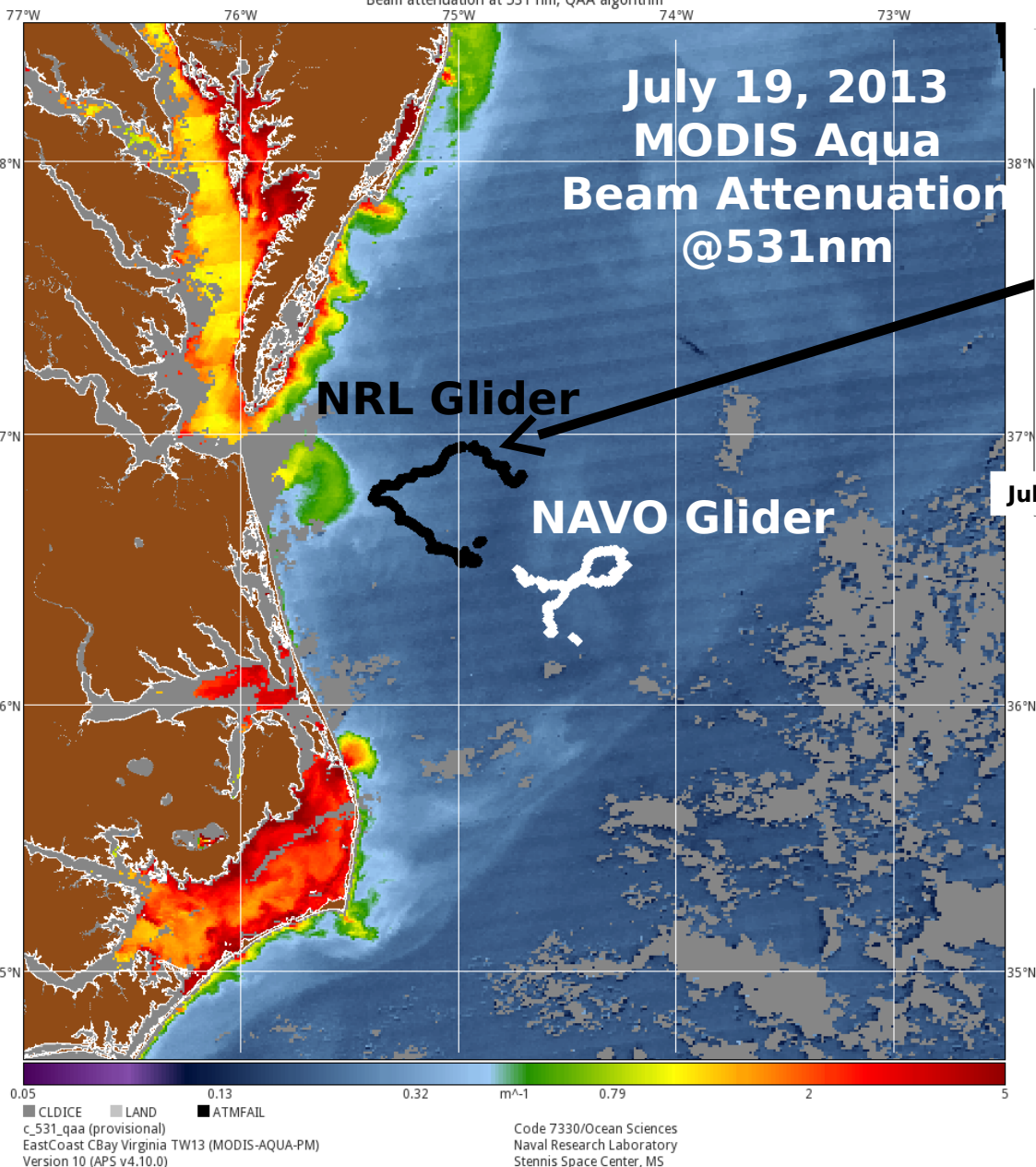
Predicting the 3D Optical Environment by Fusing Satellite Gliders and Models during Trident Warrior July 2013



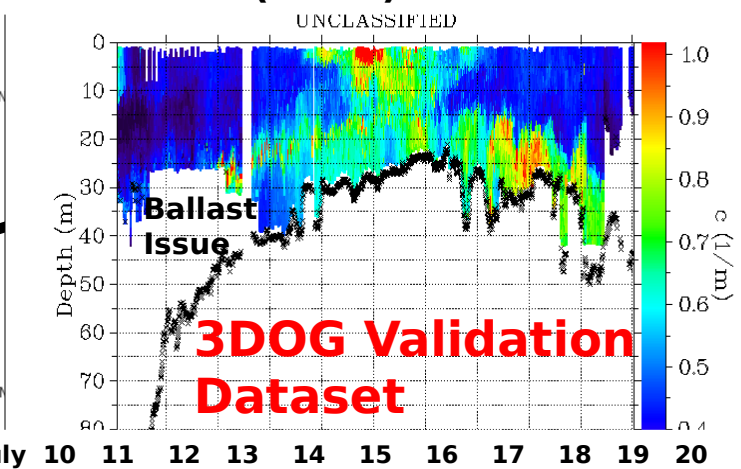
aqua.2013200.0719.D.L3_Mosaic.modis.TRW.v10.1000m.hdf

Fri Jul 19 18:25:14 2013

Beam attenuation at 531 nm, QAA algorithm



NRL Glider (sl082) Beam-c 531nm



- Selected optical profiles (20) were used to generate/tune coefficients for 3D optical model
- Non-selected optical profiles (330) are being used for validation
- NAVO glider omitted from 3DOG evaluation due to issue with elevated optics in deep ocean.

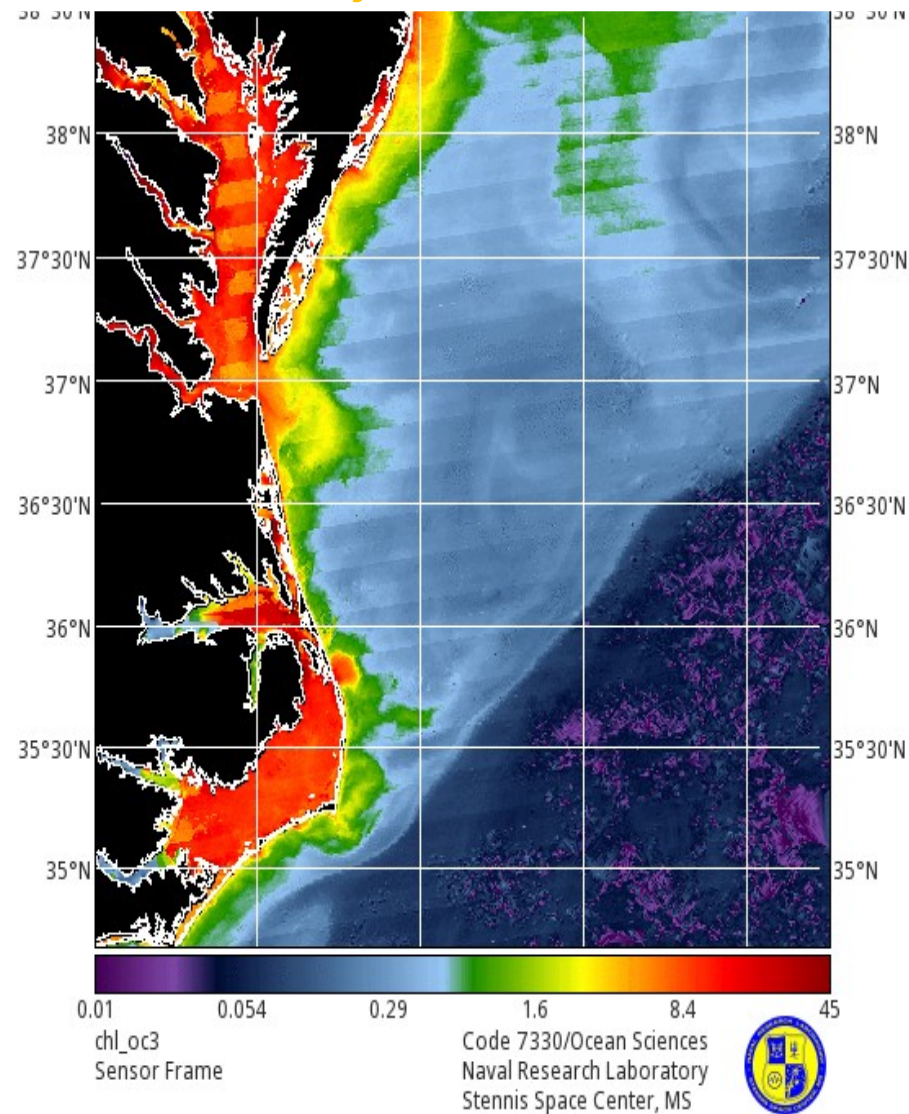
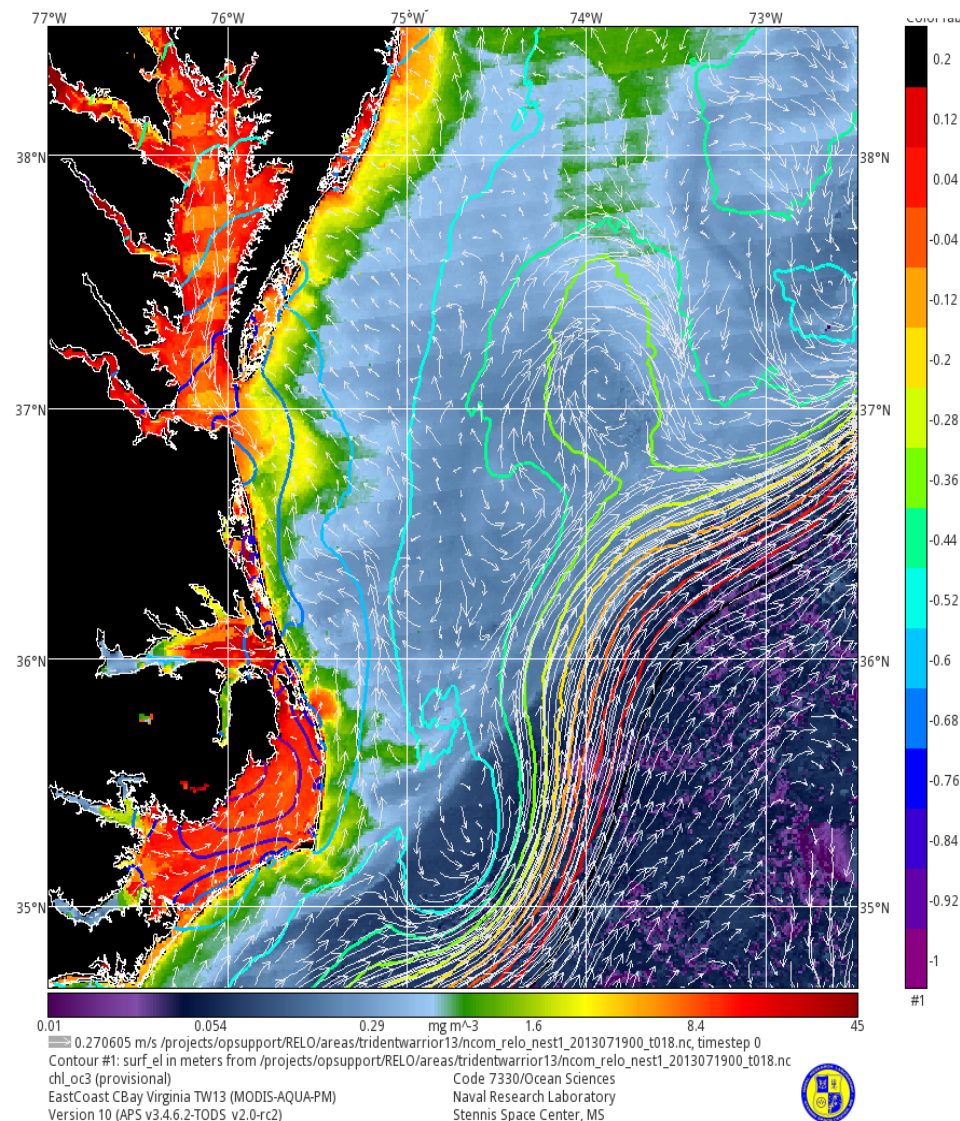


Forecasting Surface Bio-Optical Properties Trident Warrior 13 Merging Satellite Bio-Optical Properties and Modeled Currents - BIOCAST v1.0



19, 2013 MODIS Aqua Chlorophyll Initialization Field w/ Model Currents & SSH Contours

19, 2013 MODIS Aqua Chlorophyll Hour (Hourly) Forecast - Animation





Forecasting Surface Bio-Optical Properties

Trident Warrior - Chesapeake Bay, VA – July 18, 2013

Forecast Steps:

Seed the Model
with Satellite Bio-
Optical Products

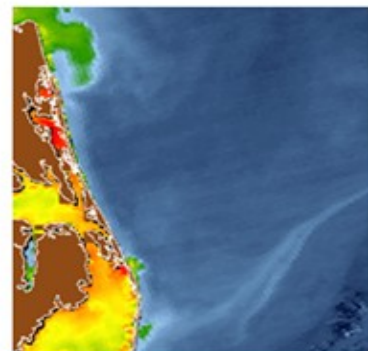


Advect Satellite
Properties forward
(hourly steps)
Conservative Tracers

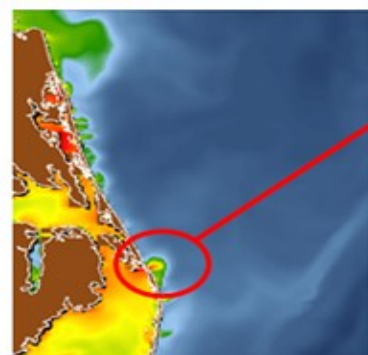


Compare with Next
Days Satellite Bio-
Optical Products

c531nm / Optical Field

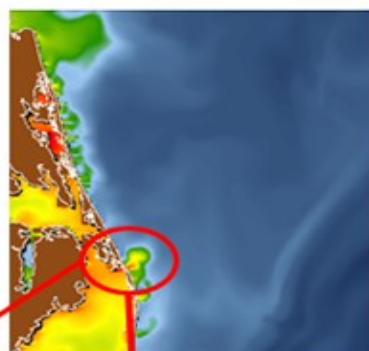


July 18, 2013
Seed /
Initialization
Field

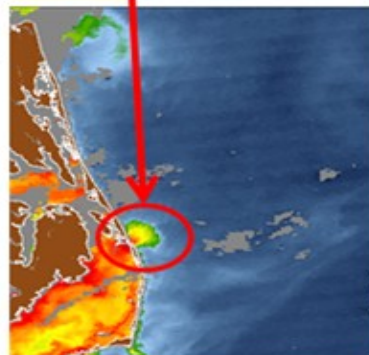


12 Hour
Forecast

Turbidity plume
expansion out of
Orgeon Inlet, NC

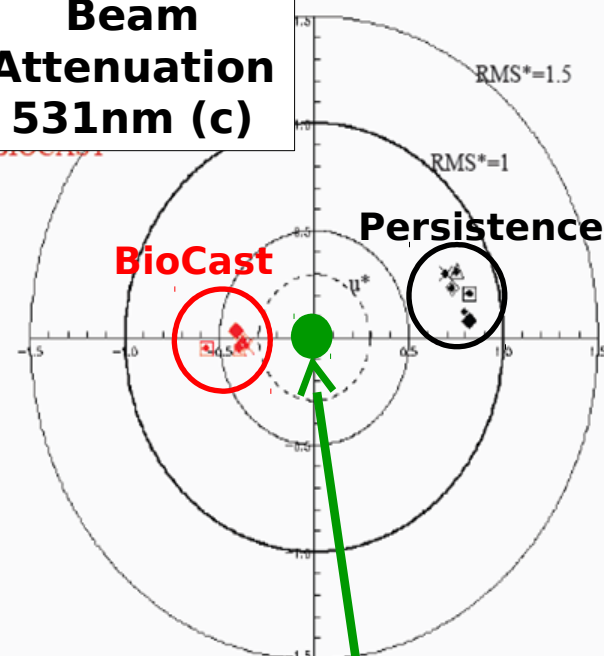


24 Hour
Forecast
For
July 19, 2013



Actual
Satellite
Image
July 19, 2013

Beam
Attenuation
531nm (c)



Bull's-eye = no
error

Statistical summary diagram compares 30-day latest pixel composites (persistence) against the next-day MODIS satellite product (black) and BIOCAST 24-hour forecast against the same next-day MODIS product (red). Statistics are generated from 60-days



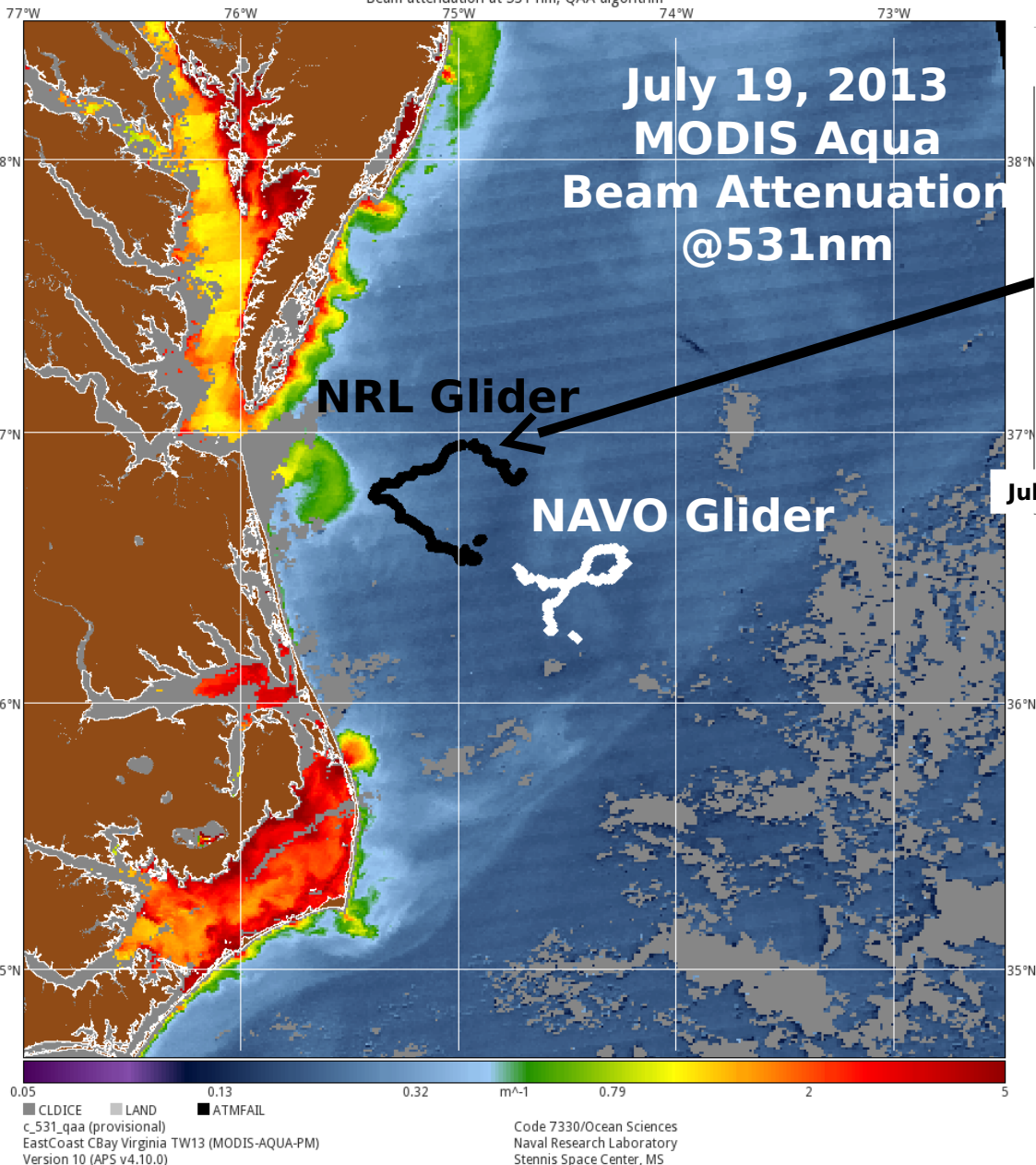
Predicting the 3D Optical Environment by Fusing Satellite Gliders and Models during Trident Warrior July 2013



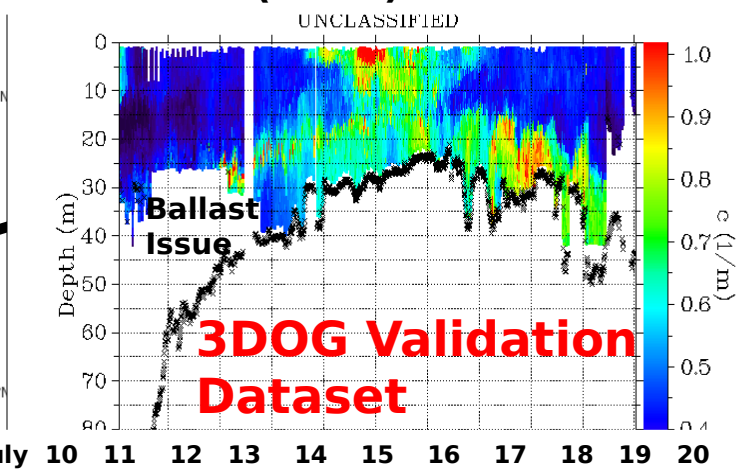
aqua.2013200.0719.D.L3_Mosaic.modis.TRW.v10.1000m.hdf

Fri Jul 19 18:25:14 2013

Beam attenuation at 531 nm, QAA algorithm



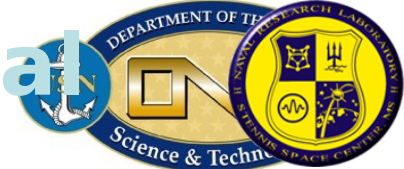
NRL Glider (sl082) Beam-c 531nm



- Selected optical profiles (20) were used to generate/tune coefficients for 3D optical model
- Non-selected optical profiles (330) are being used for validation
- NAVO glider omitted from 3DOG evaluation due to issue with elevated optics in deep ocean.

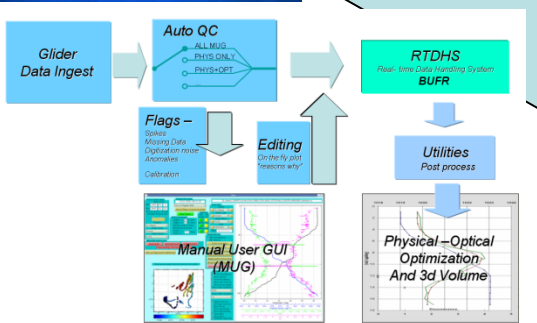


Generation of the 3D Optical Volume (3DOG)

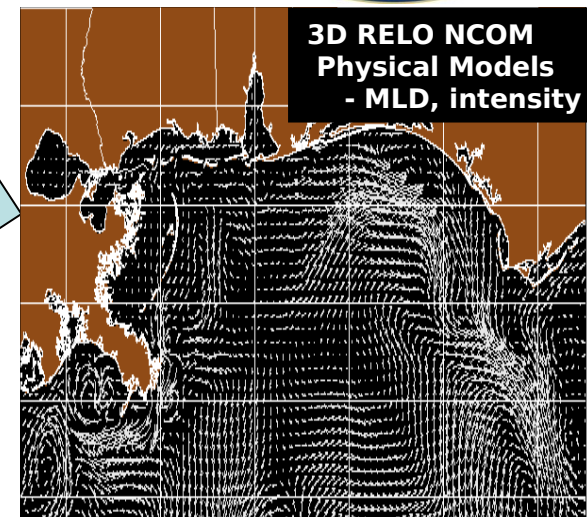
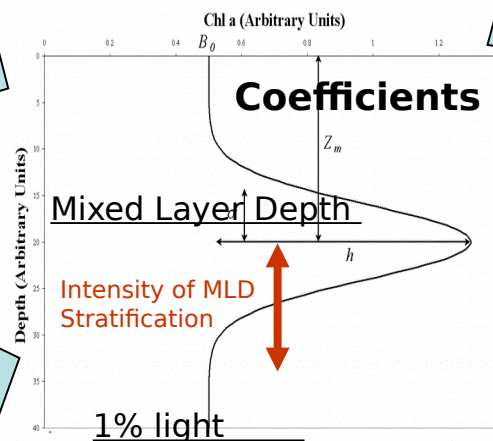


Gliders

Optics and Physics
LAGER - optics
VTR v1



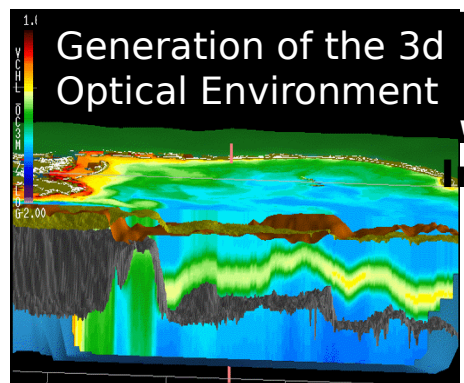
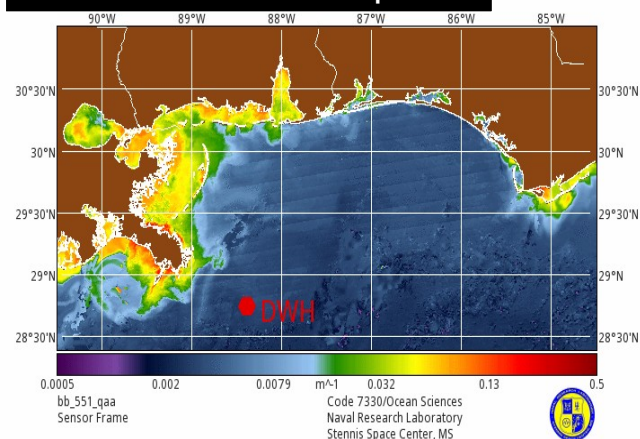
"Fusion of the Data sources"
Optics (surface) to physics (subsurface)
Derived through optimization of a
Gaussian Model



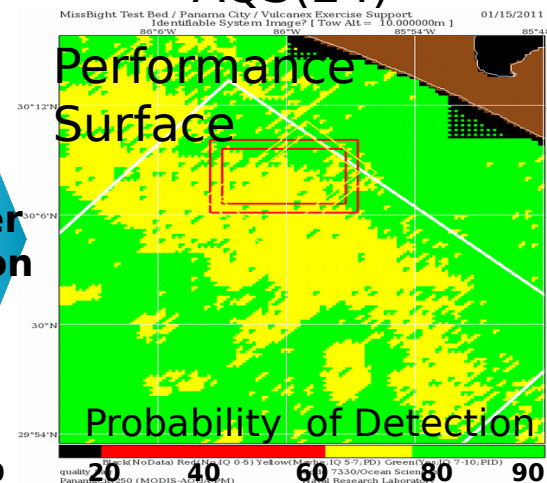
Environmental Decision Aides
For Operational Planning
EOIDS (EODES)
AQS(24)

Satellite Surface Optics

9.nc



Warfighter
Information



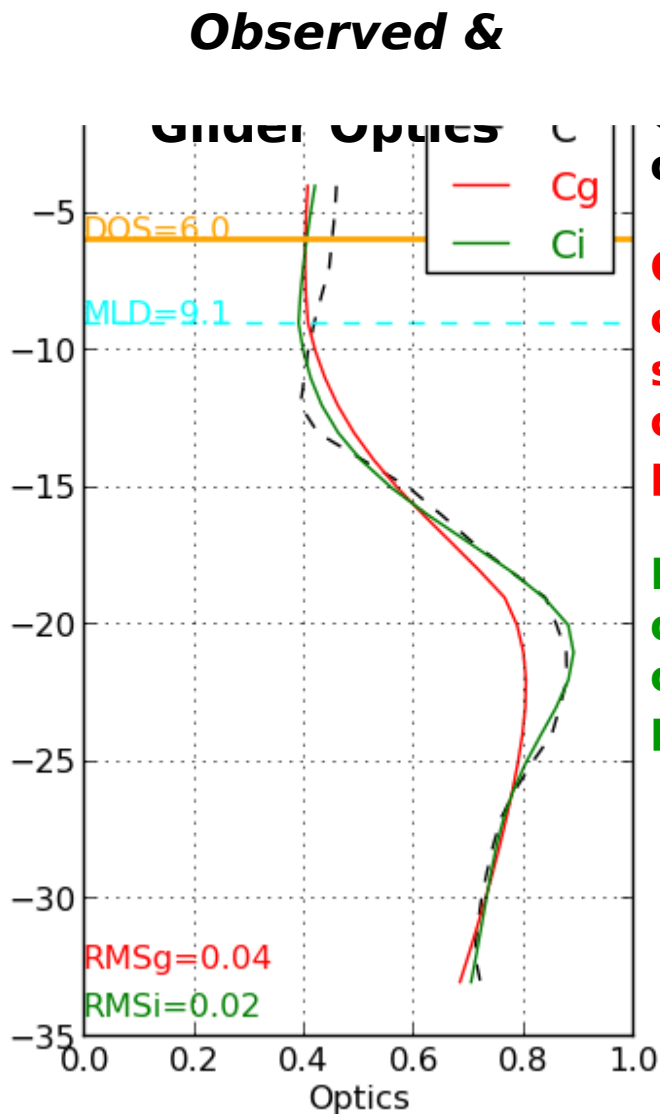
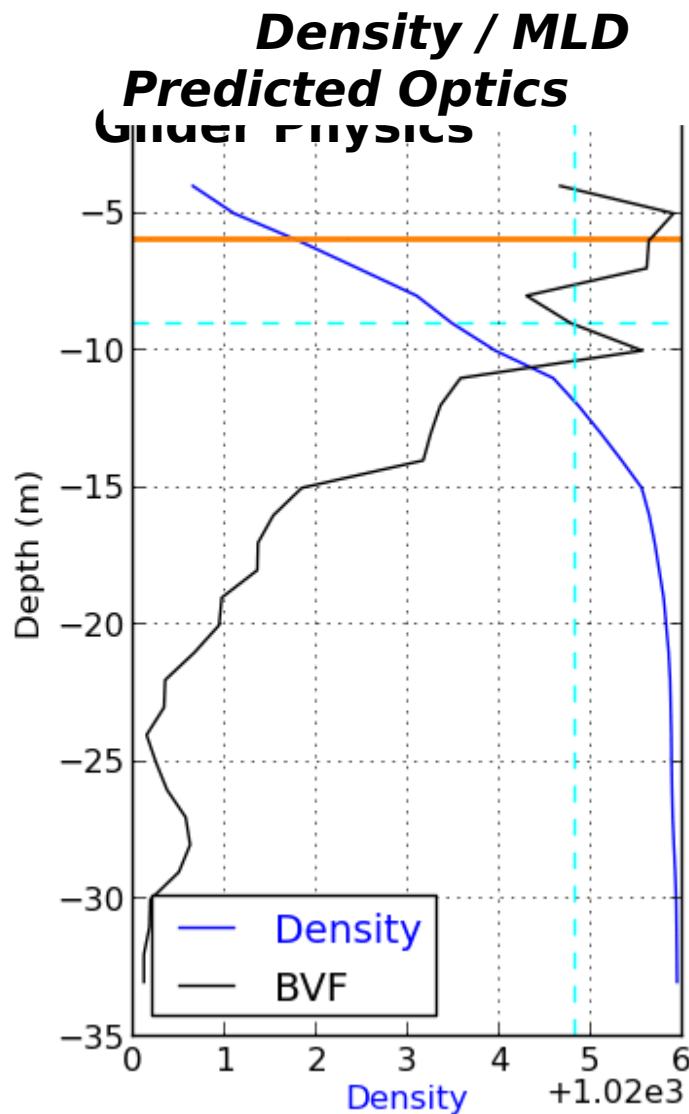


3DOG Glider Optimization - Tuning Coefficient

Trident Warrior - July 17, 2013

3DOG Predicted Beam Attenuation 531nm Profiles

Defining Regional Optical/Physical Relationship



**Glider Insitu Beam-
c**

**Global optimized
coefficients - 20
selected profiles
covering 24 hour
period**

**Individually
optimized
coefficients - each
profile**

Mean RMS

0.05

0.02



AQS-24 Snippets (4/7/11) Step-Ups

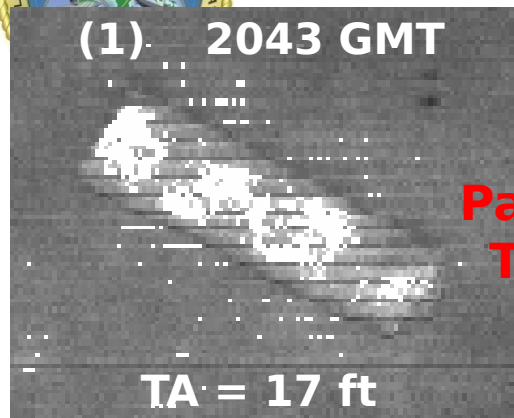
4/7/11

Performance

Predictions

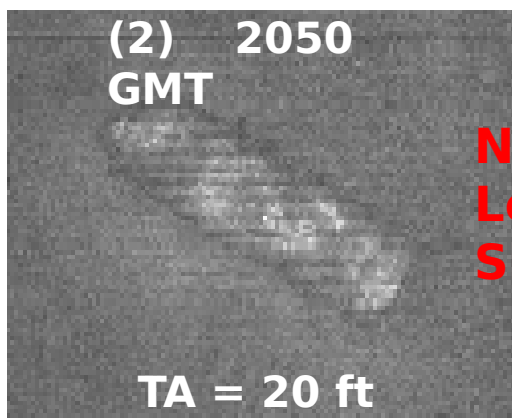


(1) 2043 GMT



**Same Object
Passed Over Multiple
Times at Increased
Tow Heights**

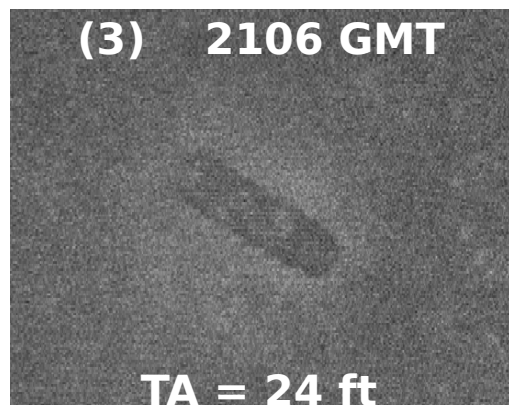
(2) 2050
GMT



**Note:
Loss of Contrast,
Size and Detail**

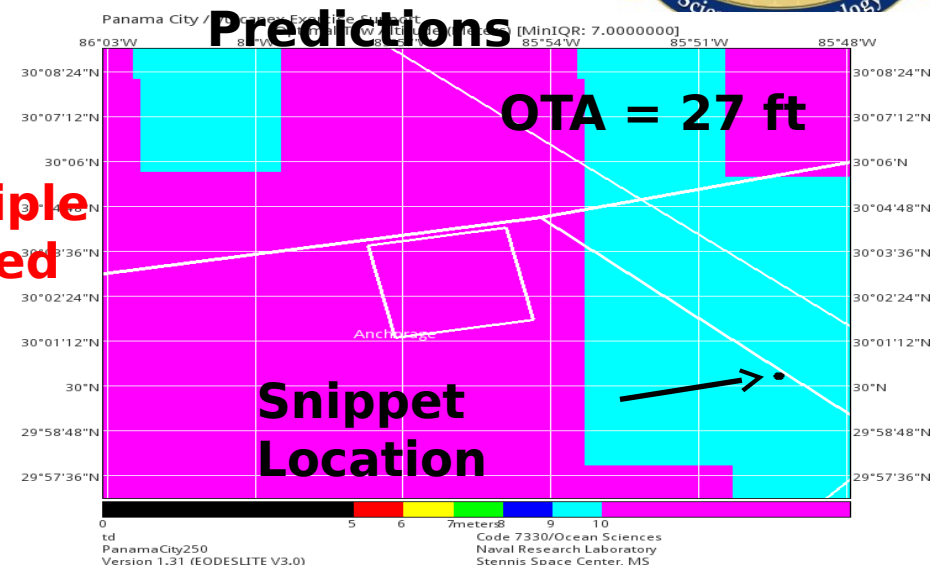
TA = 20 ft

(3) 2106 GMT



TA = 24 ft

**~20% Increase
in Predicted Tow
Heights = More
Efficient
Planning and
Clearance Times
with Same
Probability of**



**Target Identification @ 19.7 ft Tow
Altitude**

